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BEST PRACTICE COMMISSIONING DATABASE FOR GREEN BUILDINGS

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ABSTRACT

For more than 15 years, the international *Ebert Group* (represented in the US by *Ebert & Baumann Consulting Engineers, Inc.*) has been working on Commissioning (Cx) projects for existing commercial buildings. The findings of the analysis of 1,000 buildings of the *City of Munich*, Germany, the collection of measures for the worldwide building stock of *Siemens Real Estate* (*SRE*), and further projects led to a comprehensive database with measures dealing with the reduction of energy consumption for heating, cooling, ventilation, lighting, transportation and water consumption, as well as the reduction of waste and material flow. The focus of these projects in particular, was set on optimization measures with a maximum of 5 to 10 years for amortization. For a generic, and worldwide use, the measures are classified into four climate zones (hot and dry, hot and humid, temperate, and cold). The descriptions contain information for each measure about

- the technical details for the realization,
- conditions and restrictions,
- impact / implication on further measures,
- costs, as well as
- benefits.

Same measures can show different cost-benefit-ratings for different climates.

The first part of the paper deals with the structure of the database and the estimation of cost benefit relations of the measures.

The second part focuses on exemplary measures for hot and humid climates like

- adapting air flow rates to actual demand,
- demand control for mechanical ventilation,
- adapting air humidity to actual requirements, and
- free cooling.

With the intention to collect and provide further best practice examples for improving building systems and building operation, it is planned to make a web-based version of the database available for public access.

OBJECTIVE OF THE DATABASE

Independent of the size, technical complexity or geographic location of individual sites, the local building managers all face the same challenge: to operate buildings and building systems professionally while meeting the tenants' requirements for a pleasant and comfortable work environment. In times of increasing cost pressures, rising energy prices and a wider sense of global responsibility, more and more attention is given to reducing the consumption of natural resources.

This is exactly what the *EB Best Practice Commissioning Database for Green Buildings* is for: providing advice and support to ensure greater efficiency in the consumption of resources for worldwide real estate inventory. It is not about the latest inventions and technical innovations, but about existing and proven best practice approaches that work. Use it as a general catalog of practical measures and as a checklist for taking advantage of potential savings. Its purpose is to provide a compendium of cost-saving measures via internet that can be continually updated.

Usually, measures to enhance energy efficiency are realized together with repairs or renewals of systems or major building renovations or refurbishments. In these cases, energy savings are often a welcome by-product that can be counted as an additional benefit.

However, reduction in energy consumption (and other resources, too) and the related costs can also be achieved for its own reason as an economic measure as part of a continuous optimization process, e.g. initiated through a benchmark. Such measures must be technically feasible and make a lot of economic sense by themselves — and it is exactly this type of “quick-win“ measure that is the focus of the *EB Best Practice Commissioning Database for Green Buildings*. The database contains both, energy-saving measures that do not require any capital spending as well as capital intensive measures, that then pay for themselves within five to ten years due to cost savings. Measures in terms of adjustments of control settings and modification of control sequences have been purposely excluded from this database, since they are included in a different *Operation Diagnostics Database*.

USING THE DATABASE

Buildings and their technical equipment exist above all to provide the people who live and work in them with a comfortable environment and protection from external influences like climate, noise, and sometimes even pollution. Thus, the requirements for building envelopes and technical systems vary as greatly as the prevailing climatic conditions of the locations where the buildings are situated. Subsequently, also the relevance, technical feasibility, and not at least the profitability of individual measures to improve energy efficiency depend largely on the climate of the particular location. Therefore, the measures have been divided into four climate zones, based on the general thermodynamic functions that affect HVAC systems:

- *Tropical zones*: Areas in which only *cooling* and *dehumidification* play a role.
- *Dry and hot zones*: Areas where the focus is on *cooling* and possibly *dehumidification*.
- *Moderate zones*: Areas where space conditioning is needed in summer as well as in winter; air conditioning systems often provide all four thermodynamic functions (*heating*, *cooling*, *humidification*, *dehumidification*).
- *Cold zones*: Only *heating* and possibly *humidification* play a role; air conditioning systems do not generally require cooling or dehumidification due to climatic conditions.

Regardless there are differences, there is no further differentiation used in the database for *moderately cold* and *moderately warm* climates, as there is neither for *maritime* and *continental* climates. Possibly relevant influences or limitations are mentioned within the detailed description of each single measure.

Based on an equipment-specific approach, the measures are broken down into the following groups:

- Water
- Heating
- Ventilation and Air Conditioning
- Electrical Power
- Office Equipment
- Consumables and Waste

The following summary lists selected measures with their general suitability for various climate zone and rates them as “well suited” (+), “limited suitability” (•), and “not suited“(-).

		Tropical zones	Dry and hot zones	Moderate zones	Cold zones
Heating	Disconnecting boilers from the water supply	-	-	+	+
Ventilation/Air Conditioning	Adapting air flow to demand	+	+	+	+
Ventilation/Air Conditioning	Adapting the air humidity to the requirements	+	+	+	+
Ventilation/Air Conditioning	Changing the absorption behavior of building surfaces	•	+	-	-
Ventilation/Air Conditioning	Adjusting the operating hours of ventilation systems	+	+	+	+
Ventilation/Air Conditioning	Turning on chillers based on the outside temperature	-	+	+	-
Ventilation/Air Conditioning	Insulating air conduits	-	-	•	+
Ventilation/Air Conditioning	Using evaporative cooling	-	-	+	-
Ventilation/Air Conditioning	Using single-room controls	+	+	+	+
Ventilation/Air Conditioning	Using a frequency converter for the ventilation system	+	+	+	+
Ventilation/Air Conditioning	Using window contacts	+	+	+	+
Ventilation/Air Conditioning	Using night ventilation	-	-	+	-
Ventilation/Air Conditioning	Using heat recovery systems	+	+	+	+
Ventilation/Air Conditioning	Setting the pressure boosting system	+	+	+	+
Ventilation/Air Conditioning	Replacing the chillers	+	+	•	-
Ventilation/Air Conditioning	Replacing air filters	+	+	+	+
Ventilation/Air Conditioning	Free cooling	-	-	+	-
Ventilation/Air Conditioning	Variable chilled water temperature	•	+	+	-
Ventilation/Air Conditioning	Controlling the air mix	+	+	+	+
Ventilation/Air Conditioning	Light contacts and delayed OFF switch for exhaust fans	+	+	+	+
Ventilation/Air Conditioning	Using cool storage	•	+	•	-
Ventilation/Air Conditioning	Optimizing the outside air intake	+	+	+	-
Ventilation/Air Conditioning	Optimizing the functionality and use of sunshades	+	+	+	-
Ventilation/Air Conditioning	Closing the shutters of ventilation systems	-	-	+	+
Ventilation/Air Conditioning	Changing the recooling system	+	+	+	-
Ventilation/Air Conditioning	Using ground or surface water for cooling	-	-	+	-
Ventilation/Air Conditioning	Variable cooling circuit temperatures	+	+	+	-
Power	Lowering the temperature of hot water heaters	+	+	+	+
Power	Improving lighting efficiency	+	+	+	+
Power	Using reactive current compensation	+	+	+	+
Power	Using power load management	+	+	+	+
Power	Using cogeneration/trigeneration	+	+	+	+
Power	Using movement sensors combined with light sensors	+	+	+	+
Power	Using timers	+	+	+	+
Power	Removing mobile electrical heating and cooling equipment	+	+	+	+

Table 1: List of selected measures.

Even though the division into climatic zones is based on HVAC fundamentals, other systems show similar sensibilities. As for example the availability and therefore the costs for water depend significantly on climate conditions. Whereas measures for electrical energy savings (e.g. improving lighting efficiency) are only secondarily dependent upon climate differences. Of course, local characteristics and particularities have to be taken into account when evaluating the reasonability and estimating the cost-benefit ratio of certain measures in detail.

The description of each measure is structured as follows:

At the beginning of each measure, the *Requirements* explain the conditions and outlines under which the respective measure should be considered. That can be a certain building type, a particular system configuration, typical operation schedules, user behavior, etc.

The *Savings Chart* (see Figure 1) then shows which resources are affected by the respective measure. The resources are broken down into

- Heating consumption [kWh]
- Heating demand [kW]
- Electric power consumption [kWh]
- Electric power demand [kW]
- Fresh water
- Waste water / sewage water

Heating is not further sub-divided into the heat or fuel source (district heating/steam, gas, oil, etc.), whereas cooling is broken down to electricity in general. This breakdown enables a direct link to billed energy resources and thus provides a good understanding and the possibility for common benchmark practice. The chart also shows the amount of potential savings relative to the overall consumption of the respective resource. Only the affected resources are shown in the saving chart for the respective measure. The given savings are based on calculations as well as on experiences from realized projects.

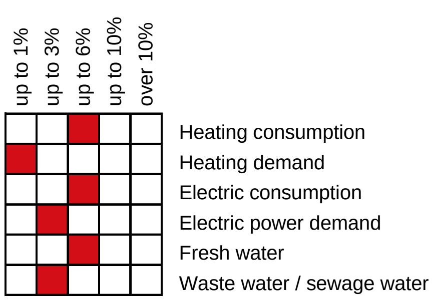

Figure 1: Savings chart for different resources.

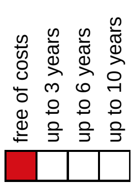

Figure 2: Amortization chart.

In a similar way, the *Amortization Chart* (see Figure 2) provides an overview of the return on investment that can be expected under the most favorable project-specific conditions and in the most suitable climate region. At the moment, the calculation is based on average energy prices for 2005 in Germany. A further development for a globally used internet based database would include the possibility to calculate the cost-benefit ratio of each single measure with individual energy costs based on the actual energy consumption. Of course, this will still be only a rough estimate that cannot and will not aim to replace a professional engineering analysis under local technical and economical conditions and restrictions.

The technical realization of each measure is then described briefly. Instructions are given for the correct systems and equipment selection and dimensioning. Design and installation issues are discussed as well as interactions with related measures that could lead to additional benefits and savings.

The *Sources and Links* section finally lists references to additional information and available best practice examples.

DESCRIPTION OF EXEMPLARY MEASURES

ADAPTING AIR FLOW RATES TO ACTUAL DEMAND

Basic Conditions and Requirements

Mechanical ventilation systems are often operated at higher ventilation rates than actually needed because of improper initial commissioning or modifications in occupancy and/or usage. This measure should be considered for school buildings, office buildings, public buildings, etc. (class rooms, conference centers, meeting rooms, assembly rooms, etc.).

It has to be considered whether the ventilation system is used for providing fresh air for the occupants only, or also for heating and/or cooling of the space.

Cost Effectiveness and Resources

Reduction of energy demand and energy consumption for heating and cooling due to reduced outdoor air rate (possibly higher mixing air rate). In case of a reduction of the overall air flow rate additional savings in the electric demand and consumption for supply and return air fans can be achieved as well.

There are no major costs, since fans and fan drives usually provide the possibility to change the speed. Thus, only labor costs have to be taken into account.

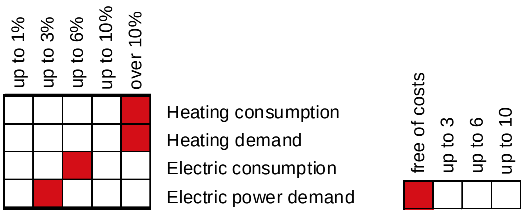

Figure 3: Savings and Amortization Chart for adapting air flow rates to actual demand.

Measure

Reduce either the overall air flow rates or the outdoor air flow rate (fresh air rate) of the mechanical ventilation systems to meet actual requirements.

National and international standards define occupancy- and space-related fresh air supply rates based on the respective space utilization. Determine the appropriate amount of fresh air required and set the ventilation flow rates accordingly by adjusting the fan speed or the belt pulleys. With some fan types you may also be able to adjust the flow rate by adjusting the clearance of the impeller wheel. If available, take the characteristic curves of the fan and its drive technology into account.

Do not reduce the air flow rate by installing additional dampers (or closing existing dampers) since this would increase the system pressure and, thus, increase the power consumption of the fans instead to reduce it.

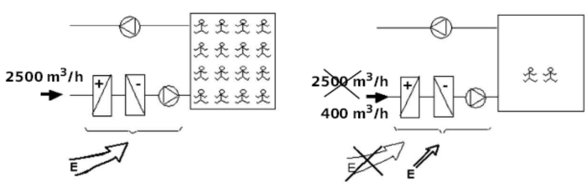

Figure 4: Demand control for AHU's depending on occupancy.

For building spaces with varying occupancy over time, this measure should possibly be combined with a demand control for mechanical ventilation (see next measure).

DEMAND CONTROL FOR MECHANICAL VENTILATION

Basic Conditions and Requirements

Ventilation systems with constant air flow rates usually provide unnecessary high ventilation rates, especially for spaces with varying needs as for example when occupancy varies over time. The additional installation of frequency converters for the fan drive provides significant saving potential.

Cost Effectiveness and Resources

This measure leads to significant reductions of energy consumption for heating and cooling, as well as for electrical consumption due to reduced operating hours at full load conditions.

The measure requires investments for modifications for the AHU (frequency converter, maybe VAV boxes, etc.) as well as for the BAS (additional sensors, modified control logic, etc.).

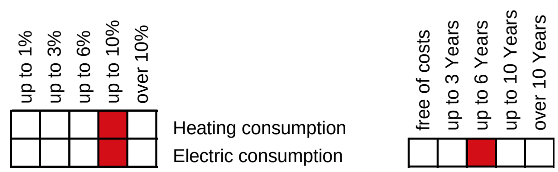

Figure 5: Savings and Amortization Chart for demand control for mechanical ventilation.

Measure

Ventilation systems operating with constant fan speed can be turned into variable-speed systems by installing frequency converters in connection with sensors on the load side (air quality sensors, pressure sensors, presence sensors, etc.) or timers. This enables the system to adjusts the amount of fresh air regarding the actual need due to varying occupancy or load in different building zones. The air conditioning components (heating/cooling coil, humidification, dehumidification) are then controlled regarding the reduced air flow rates.

The simplest way to realize demand control is to program the schedule of occupancy in the building automation system. Typical applicability e.g. would be school buildings with regular and periodical usage.

For buildings or building zones with less regular occupancy (like meeting rooms, for example) it is recommended to use occupancy sensors or other sensors (air quality or room temperature) to estimate the actual demand for ventilation depending on the occupancy.

It has to be taken into account if the ventilation system is used for space heating and cooling, as well. In this case, the demand control requires additional sensors to measure thermal and humidity loads, and control logics depending on room temperatures and possibly humidity.

ADAPTING AIR HUMIDITY TO ACTUAL REQUIREMENTS

Basic Conditions and Requirements

This measure can be applied to air conditioning systems and air handling units, respectively, with humidification/dehumidification function.

Cost Effectiveness and Resources

Reduction of energy demand and energy consumption for humidification and dehumidification due to utilization of the entire range of comfort criteria instead of a single operation stage. That leads to reduced thermodynamic treatment of the supply air, and thus, to reduced operation of single systems of the AHU's without decreasing thermal comfort.

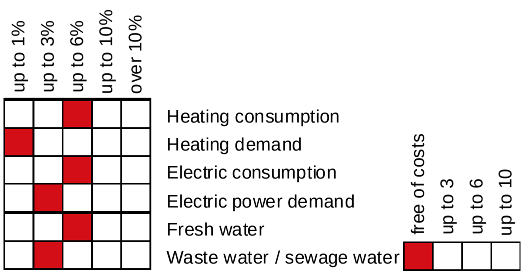

Figure 6: Savings and Amortization Chart for adapting the air humidity to actual requirements.

Measure

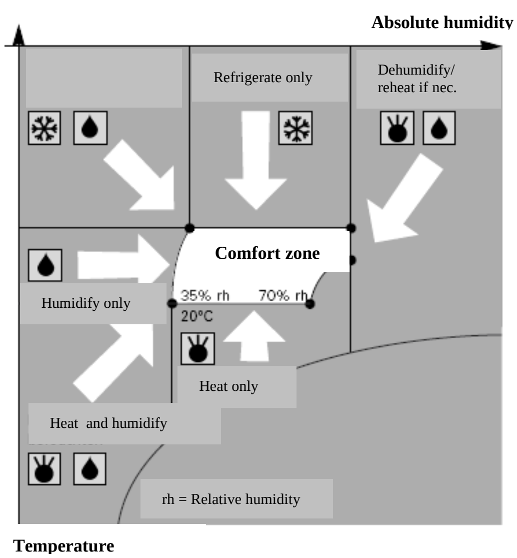

Figure 7: Comfort zone displayed in the psychrometric chart.

Comfort requirements for occupied spaces in buildings usually allow a certain range for the temperature, as well as for the humidity. In winter, the minimum relative humidity should not remain under 30 %. To prevent warm discomfort in winter, it is recommended that on the warm side of the comfort zone the relative humidity does not exceed 60 %. At summer conditions, relative humidity levels up to 80 % can be acceptable. Often, these ranges are not used, but the systems provide maximum capacity, particularly when dehumidifying. To save energy, the space (or supply air) should be conditioned only to the closest edge of the comfort zone, regarding the ambient conditions (see Figure 7).

To realize this measure, the usually fixed set point for the humidity of a regarding building space (usually controlled by the condition of the return air) needs to be replaced by a comfort zone functionality regarding the psychrometric chart in the building automation system (BAS).

FREE COOLING

Basic Conditions and Requirements

The objective of this measure is to reduce the chiller operating hours by using environmental cooling potential, provided by environmental conditions (outdoor air temperature).

This measure can be applied when cooling requirement is mainly due to internal thermal loads that are independent of the external temperature, ideally in combination with moderate cold water temperatures (e.g. cooling panels).

This measure suites best for moderate zones with frequent time periods with outdoor air temperatures below the required cold water temperatures. Anyway, there are also cases where this measure can be profitable in hot and even tropical zones.

Cost Effectiveness and Resources

The reduction of energy consumption for cooling results from reduced operating hours of the chillers. Buildings with high thermal mass can additionally be cooled during night to store cooling capacity for daytime. Possibly, the peak demand and therefore the costs for electricity can be reduced as well.

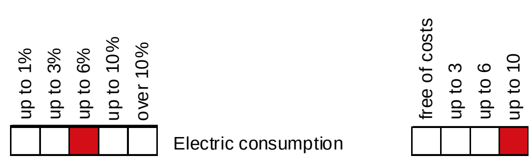

Figure 8: Savings and Amortization Chart for free cooling.

Measure

Free cooling becomes attractive as soon as the outside air temperature falls below the return temperature in the chilled water network. At that point, the cold water network is no longer cooled by the chillers, but linked via a heat exchanger to the chilled water circuit to be cooled directly by the outside air. To satisfy all cooling needs with uncontrolled cooling, the outside temperature must be sufficiently lower than the flow temperature of the chilled water network. Depending on the existing system configuration (chilled water circuits, number of chillers, number and arrangement of re-cooling systems, etc.), there may be a single mode switching point or a step-by-step switch to free cooling. This measure can be linked to the measure 'Using ground or surface water for cooling'.

CONCLUSIONS

Ebert Ingenieure has been working on commissioning of existing buildings for more than 15 years. This experience led to a database with numerous measures to 'green' buildings and to improve the energy efficiency of buildings and systems significantly. The further approach now is to make this experience commonly available to enable building owners and building operators to identify possible optimization potential for their properties. The level of measurement description is not intended to describe in detail all the technical issues to be considered and solved, but to provide sufficient information to decide whether further diagnosis and analysis could be beneficial. After this decision, a design or consultant engineer should be directed to calculate the exact cost-benefit ratio and to provide technically accurate solutions.

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